The Ordovician–Silurian boundary in Morocco

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Synopsis

At only one locality, Moulay bou Anane, in Jbilet, the *persculptus* and *acuminatus* Zones are both found, although the *acuminatus* Zone is known from many localities throughout Morocco. The early Llandovery usually consists of transgressive shales, ranging from *acuminatus* Zone to *cyphus* Zone and above in age, overlying usually unfossiliferous glacial sandstones and microconglomerates of the latest Ordovician, from one of which a *Hirnantia* fauna is recorded.

General survey

The Ordovician–Silurian boundary in Morocco is always marked by a very acute change of facies between the two systems. The glacial episode which concludes the Ordovician deposited relatively coarse material, such as sandstones, quartzites and microconglomeratic clays, which strongly contrast with the fine argillaceous or siliceous deposits which characterize the beginning of the Silurian. Consequently, the scenario is one of more or less important interruption in sedimentation, the development of glaciogenic sediments, and the transgressive development of a Silurian sea after the melting of the continental ice sheet. Under these conditions, the faunas of the two systems are naturally different, apart from the single exception of Jbilet, at Moulay bou Anane (Locality 1, of Fig. 1), where selected graptolites for the official boundary (Cocks 1985), *Glyptograptus persculptus* Salter and *Akidograptus acuminatus* (Nicholson), succeed each other in the same section. Elsewhere, only *A. acuminatus* dates the beginning of the Silurian above more or less terminal beds of the Hirnantian:

(1) in the western Anti-Atlas, at Aïn Oui n'Deliouine (Locality 2);

(2) in the eastern Anti-Atlas, at Tizi ou Mekhazni (Tizi Ambed) (Locality 3) and at Oued Bou-Leggou (Oued bou Oubagou) (Locality 3′);

(3) on the northern slope of the central High Atlas, at Ghogoult (Locality 4) and west of Tiwghaza (Locality 4′);

(4) in the substratum of the Plateau des Phosphates (Locality 5);

(5) in the Moroccan central massif in the Azrou area, at Bou Ourarh (Locality 6);

(6) in the Palaeozoic inliers of the north of the middle Atlas at Tazekka (Locality 7) and Immouzer du Khandar (Locality 8).

Some other outcrops of the transgressive Silurian are still later Rhuddanian:

(a) in the central Anti-Atlas, at Rich Mel'Alg, where graptolitic beds with *Cystograptus vesiculosus* (Nicholson), *Dimorphograptus*, and *Coronograptus cyphus* (Lapworth) are separated by a red layer from sandstones and clays of the Deuxième Bani (Upper Ashgill);

(b) in the coastal Meseta, at Oulad Saïd, south of Casablanca, where *Atavograptus atavus* (Jones) occurs in a boring;

(c) in the Qasbat-Tadla-Azrou area, at Jbel Eguer-Iguiguena, where the same association as in (a) occurs.

For (b) and (c) it is not possible to determine with precision the age of the underlying beds.

The very widespread Silurian in Morocco more generally begins either with Aeronian beneath a siliceous facies alternating with phthanitic ribbons, more sandy in the Anti-Atlas at the east of the meridian of Icht, or sometimes with argillaceous–siliceous Telychian, or, in rare cases, with the upper Wenlock and/or Ludlow.

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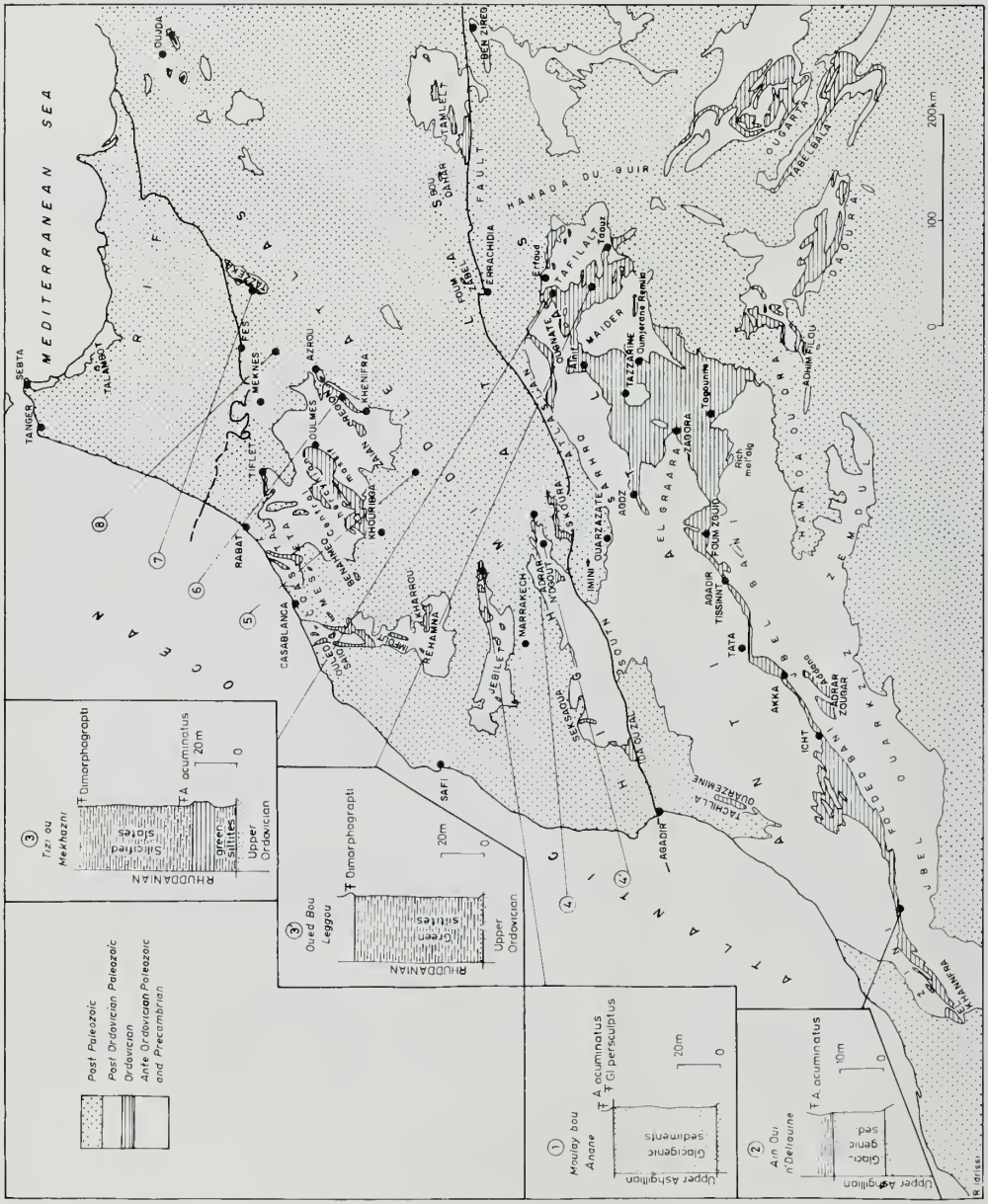

Fig. 1 The Ordovician outcrops of northern Morocco and ten localities with *Akidograptus acuminatus* described in the text.

Description of partial sections

(1) *Eastern Jbilet, Moulay bou Anane, Locality 1* (Topographical Sheet Attaouia ech Chaïbia, 1:50 000, at x = 322, y = 157·2) (Fig. 1). Roch (1939) described this area as forming part of the 'Mountains to the East of Marrakech'. Huvelin (1977) emphasized the peculiar features of the Hercynian massif of Jbilet. Huvelin and others refined the section near the boundary in 1980. Roch only pointed out that 'Miss G. Elles and G. Waterlot have recognised: *Monograptus* (sic) *modestus*, *M. sandersoni*, *M. cyphus*, *M. revolutus*, *Glyptograptus incertus*, *G. persculptus*, *Climacograptus Törnquisti* and *Cl. normalis* from the base of Llandovery' (p. 113). Specimens of *Glyptograptus persculptus*, determined by G. Elles, were obtained from a siliceous sandstone, weathered pink-beige, but more greyish on fresh fracture, in beds on which they are nearly orientated. They are of great size, the septum always starting at the fourth or fifth theca, and they are preserved as internal moulds, in whole or half relief.

Vertical section 1 summarizes more recent collections. The usual suite of terminal Hirnantian occurs over 20 m and consists of microconglomeratic clays, argillites, and sandstones with orientated sedimentary features. This is followed by a layer of quartzose sandstone not much different from those of Roch, but coarser, which yields dispersed *G. persculptus* with a few more irregularly orientated and smaller forms with a septum beginning at a lower level (in the third theca when visible). They are always internal moulds and are apparently narrower than those identified by G. Elles, but they show more relief. The thickness of the layer is 30 cm and it can be presumed that the Roch assemblage is rather nearer the top than the base.

Above this coarse facies, and without transitional beds, pink and pink-beige shales with a little mica and with a very fine cleavage, contain at their base: *Climacograptus normalis* (Lapworth), *C. miserabilis* Elles & Wood, *C. rectangularis* (M'Coy), *Diplograptus modestus* Lapworth, *Akidograptus ascensus* Davies and *A. acuminatus* (Nicholson). The thickness of this argillaceous level is 30 cm and occurs below alternations between more phthanitic beds and more or less siliceous clays which terminate the Rhuddanian. The boundary is therefore very sudden and with a sharp change of facies.

(2) *Western Anti-Atlas, Ain oui n'Deliouine, Locality 2* (Topographical Sheet Tiglit, 1:50 000, at x = 1076·4, y = 764·2). The boundary was figured in some detail in Destombes *et al.* (1985: 242, fig. 46). Above green microconglomeratic strata representing the glacial upper Ordovician, a red bed makes a clear transition with argillites which are very similar in colour, although a few are greener, and shows the same alteration and preservation for fossils as at Moulay bou Anane, although the cleavage is coarser. At the contact there is *C. normalis* and *D. modestus* and two metres above a single, small, aseptate specimen of *G. persculptus*, together with *C. normalis*, *C. transgrediens* Waern, *D. modestus*, and *A. acuminatus*.

The similarities between the two areas are striking for the early Silurian beds and, from the palaeontological point of view, the abundant *D. modestus* shows some intraspecific variations which recall Davies's (1929) considerations on the similarities of *G. persculptus* and *D. modestus*, and whether it is a case of convergence or of real relationship. Internal moulds in iron-oxides only emphasize, once again, all the pitfalls in determining deformed graptolites by comparison with material which has preserved its proteic skeleton. Finally, from these two localities, which appear to be the most characteristic of those actually known from Morocco, it is difficult to imagine any Ordovician–Silurian boundary without a break.

(3) *Eastern Anti-Atlas, Tizi ou Mekhazni (Tizi Ambed), Locality 3 and Bou Leggou (Oued Bou Oubagou), Locality 3'*. A peculiar feature of the sections near the boundary is the presence, above conglomeratic sandstones and quartzites and lenses with very coarse green and pink sandstones, of a green siltstone with a very probable hard ground between the two deposits.

(a) At Tizi ou Mekhazni (Topographic Sheet Erfoud, 1:100 000, at about x = 588·8, y = 73·8), Destombes *et al.* (1985: 257–258, figs 54 and 55) report 10 m of greenish silts followed by a black marker bed about 10 m thick of very fine silicified slates with tuff layers, followed by 75 m of fine silicified white, pink and reddish violet slates, the base of which includes *C. normalis*, *C. transgrediens*, *D. modestus*, *A. ascensus*?, and *A. acuminatus* in the first 5 m. The

Rhuddanian and the Aeronian continue up to the *M. sedgwickii* Zone within 125 m of siliceous sandstones, sometimes in plaquettes which weather to a very dark ferrugineous colour, but lighter on splitting.

(b) At Bou-Leggou (Topographical Sheet Erfoud, 1:100 000, at about x = 589·2, y = 56·6), the Rhuddanian includes about 60 m of green silts which contain nine levels with classic climacograptids (*Cl. normalis*, *transgrediens*, *praemedius* Waern, *medius* and *rectangularis*), which are sometimes crossed by small sandy nodular structures. Towards the top, at the transition with siliceous shales, *Dimorphograptus confertus* Lapworth and *D. confertus* cf. *swanstoni* Elles & Wood are found, showing a difference in thickness for the first part of the Silurian between the two localities. No trace of the black marker bed can be seen at Bou Leggou.

These sections give rise to a problem in the appreciation of the precise age for the base of the silts. However, given the usual conditions of sedimentation between the end of the Ordovician and the first Silurian and the fact that there is no proof of *A. acuminatus* at the beginning of its biozone, one can, for cartographical purposes, take the Silurian as beginning with the silts. It remains to analyze the mineralogy of the black marker beds, and perhaps also the siliceous shales, to see whether they reflect volcanic activity, even if only very distant from this district of the eastern Anti-Atlas.

(4) *On the northern slope of the central High Atlas, at Ghogoult* (*Locality 4*) *and east of Tiwghaza* (*Locality 4'*). The important Hercynian tectonics which are manifest in the central High Atlas, formerly known as the 'Mountains to the East of Marrakech' (Roch 1939) or 'Demnate Atlas' (Lévêque 1961), do not enable us to establish a sure succession for the boundary in this part of Morocco. The Silurian with *A. acuminatus* is present in the allochthonous inliers of Aït Mallah and Aït Mdioual (geological map Azilal 1:100 000, 1985) and in the autochtonous deposits to the west of Tiwghaza (boundary of topographical sheets Telouat and Skoura 1:100 000).

In Aït Mallah, *C. normalis*, *D. modestus*, *A. acuminatus*, *C. vesiculosus*, *Monograptus revolutus* s.l. (Kurck), *Pribylograptus incommodus* (Törnquist) and *A.* cf. *atavus* have been identified; in Aït Mdioual, only the lower third in argillaceous or argillaceous-siliceous shales, with a very thin cleavage (overlain by drier, resonant shales, sometimes with drifted micas), and higher coarser beds with *C. cyphus*. The relations with the Ordovician cannot be defined since the earlier Silurian 'constitutes a level of preferential disharmony' (Jenny & Le Marrec 1980).

West of Tiwghaza, *D. modestus*, *A. acuminatus* and *C. vesiculosus* are recognized from the base of the first 5 m of sandy, coarse, micaceous shales underlying siliceous and phthanitic ones of the Llandovery succession. Jenny & Le Marrec (1980) described the last three metres of the upper Ordovician as composed of classic 'massive or irregular decimetrical sandstones-quartzites, sometimes with oscillation-ripples, whitish colour with dark patina and black microbrechic or microconglomeratic sandstones or clays with round and matt quartz'.

(5) *In the substratum of the Plateau des Phosphates* (*Locality 5*). An oil-boring—BJ 105—on the geological map Qasbat Tadla (1:100 000, 1985, at x = 417·7, y = 216·8) terminated at a depth of 1017 m in the upper Ashgill. In a fragment of core between 963 to 988·5 m, in an argillaceous, graphitic, more or less siliceous facies, the lowest associations contain: (a) more argillaceous than siliceous beds with many slip planes with *C. normalis*, *C. rectangularis*, *D. modestus*, *A. acuminatus*, followed by (b) a more siliceous layer with the same association underlying the *C. vesiculosus*, *Dimorphograptus* and *C. cyphus* Zones. Although information is insufficient to define the boundary, a sudden change in facies (here between 988·5 and 1017 m) is found, with the same pattern as in other areas.

(6) *In the Moroccan central massif, Azrou area, at Bou-Ourarh* (*Locality 6*) (Topographical Sheet Aïn Leuh, 1:50 000, at about x = 503·5, y = 302·5). The Silurian here occurs as a siliceous facies alternating with real phthanites weathering light grey. It is the 'Formation dite de Mokattam' of Choubert (1956). It always lies upon ridges of sandy or even quartzitic material, which are more resistant in the landscape, and which can be assigned to the upper Ordovician without more precision in dating. Graptolites are found more or less at the contact. At one locality, there is *C. normalis*, *C. medius*, *C. rectangularis*, *C. vesiculosus*, *A. acuminatus*, *Glyptograptus* sp.

or *Orthograptus* sp., *P. incommodus*, *A.* ex gr. *atavus* and *Raphidograptus toernquisti* (Elles & Wood). The beds with *A. acuminatus* are less compact than those with *C. vesiculosus*. Rhuddanian and Aeronian rocks with the *Coronograptus gregarius* Zone are found down a small valley. Sandy layers occur at several levels in the Mokattam Formation and the sequence is repetitive. It is now known that this area has suffered greatly through Hercynian tectonism, so it seems that Bou-Ourarh is constructed of a number of tectonic slices in which the Silurian has often played the role of soapstones, and so it is not possible to find any Silurian beds conformably against the Ordovician sandstones. Although this district is not important for the boundary definition, it is a supplementary paleogeographical marker for the distribution of the *A. acuminatus* Zone.

(7) *In the Palaeozoic inliers of the north middle Atlas.*

(a) Tazekka (Eastern Morocco) (Locality 7). The same tectonics as at Bou-Ourarh cause repetition of the upper Ordovician and lower Silurian. At Souk et Tleta des Zerarda (Topographical Sheet Ribat el Kheir, 1:50000, at x = 594·5, y = 373·7) at the top of the usual quartzites, almost vertical upper Ashgill black argillaceous-siliceous and siliceous beds contain *C. normalis*, *C. medius*, *C. rectangularis*, *C.* probably *longifilis* Manck, *C.* probably *trifilis* Manck, *D. modestus* and *A. acuminatus*. Silurian beds follow, but not quite in the same section.

(b) Immouzer du Khandar (Locality 8). The same situation exists at the NW end of the Immouzer du Khandar inlier (Topographical Sheet Sefrou, 1:100000, at about x = 540·1, y = 353·7), where *A. acuminatus*, *C. normalis*, *C. miserabilis*, *C. rectangularis* and *D. modestus* are found in the argillaceous facies of the Mokattam Formation, but the locality is altered and schistosed, with bedding plane thrusts. This has contact with sandy pelites and big well-rounded quartzites of the upper glacial Ordovician, which are equivalent to the Upper Deuxième Bani Formation (Upper Ashgill) of the Anti-Atlas.

Conclusions

The base of the Silurian is seen in many areas of Morocco, and invariably in argillaceous facies, underlying sandstone levels and never in true phthanites. It is remarkable that in these sections no Ordovician faunas have been found, except at Moulay bou Anane. However, in the central Anti-Atlas, Tagounite area, at Jbel Larjame and at Oued Moulili, some badly preserved brachiopods are known from the upper part of the Upper Deuxième Bani Formation; these are from a more western region (south flank of Jbel Addana, south of Akka) and consist of *Hirnantia sagittifera* (M'Coy), *Eostropheodonta squamosa* Havlíček, and *Plectothyrella chauveli* Havlíček, from grits above microconglomeratic clays. These faunas are very important in dating the intra-Hirnantian tillite, and in these areas of the central Anti-Atlas the Silurian begins with a hardground followed by graptolites of later Llandovery age. We do not expect to find more significant faunas in the Ordovician rocks and future studies must turn to the sedimentology of the glacial phenomena and the volcanic influences in the eastern Anti-Atlas; and also to the description and illustration of the graptolites themselves.

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